

What is claimed is:

1. A magnetoresistance device comprising:
a magnetoresistance element including:
a free ferromagnetic layer having
reversible spontaneous magnetization,
5 a fixed ferromagnetic layer having fixed
spontaneous magnetization, and
a tunnel dielectric layer disposed
between said free and fixed ferroelectric layer;
a non-magnetic conductor providing
10 electrical connection between said
magnetoresistance element to another element; and
a diffusion barrier structure disposed
between said conductor and said magnetoresistance
element.
2. The magnetoresistance device according to
claim 1, wherein said diffusion barrier structure
has a function to prevent at least one material
out of materials included in said conductor from
5 being diffused into said magnetoresistance
element.
3. The magnetoresistance device, wherein said
diffusion barrier structure has a function to
prevent at least one material out of materials
included in said magnetoresistance element from

5 being diffused into said magnetoresistance element.

4. The magnetoresistance device according to claim 1, wherein said conductor includes at least one element selected from the group consisting of Al, Cu, Ta, Ru, Zr, Ti, Mo, and W.

5. The magnetoresistance device according to claim 1, wherein said diffusion barrier structure is formed of material selected from the group consisting of oxides, nitrides, and oxynitrides.

6. The magnetoresistance device according to claim 5, wherein said diffusion barrier structure is formed of conductive nitride.

7. The magnetoresistance device according to claim 5, wherein a through-thickness resistance of said diffusion barrier structure is smaller than that of said tunnel dielectric layer.

8. The magnetoresistance device according to claim 5, wherein said diffusion barrier structure is a film having a thickness less than 5 nm.

9. The magnetoresistance device according to

claim 5, wherein said diffusion barrier structure is made of oxide of element having a free energy of oxide formation less than those of elements
5 included in layers connected on top and bottom surfaces of said diffusion barrier structure.

10. The magnetoresistance device according to claim 5, wherein said diffusion barrier structure is made of nitride of element having a free energy of nitride formation less than those of
5 elements included in layers connected on top and bottom surfaces of said diffusion barrier structure.

11. The magnetoresistance device according to claim 5, wherein said diffusion barrier structure is made of oxynitride of element having free energies of oxide and nitride formations less
5 than those of elements included in layers connected on top and bottom surfaces of said diffusion barrier structure.

12. The magnetoresistance device according to claim 5, wherein said diffusion barrier structure is made of material selected from the group consisting of AlO_x , MgO_x , SiO_x , TiO_x , CaO_x , LiO_x ,
5 HfO_x , AlN , AlNO , SiN , SiNO , TiN , TiNO , BN , TaN ,

HfNO, and ZrN.

13. The magnetoresistance device according to claim 5, said diffusion barrier structure is an oxide layer and made of a same material as said tunnel dielectric layer.

14. The magnetoresistance device according to claim 12, wherein said oxide layer is thinner than said tunnel dielectric layer.

15. The magnetoresistance device according to claim 1, wherein said conductor includes:

a first conductor electrically connected to said fixed ferromagnetic layer without
5 involving said tunnel dielectric layer, and

a second conductor electrically connected to said free ferromagnetic layer without involving said tunnel dielectric layer, and

10 wherein said diffusion barrier structure includes:

a first diffusion barrier layer disposed between said first conductor and said fixed ferromagnetic layer, and

15 a second diffusion barrier layer disposed between said second conductor and said

free ferromagnetic layer.

16. The magnetoresistance device according to claim 15, wherein said first and second diffusion barrier layers are made of material selected from the group consisting of oxides, nitrides, and
5 oxynitrides.

17. The magnetoresistance device according to claim 1, wherein said diffusion barrier structure is disposed between a layer including manganese and said conductor or between a layer including
5 nickel and said conductor.

18. The magnetoresistance device according to claim 1, wherein said conductor includes a first conductor electrically connected to said fixed ferromagnetic layer without involving said tunnel
5 dielectric layer,

wherein said diffusion barrier structure includes a first diffusion barrier layer connected between said first conductor and said fixed ferromagnetic layer, and

10 wherein said magnetoresistance element further includes a manganese-including antiferromagnetic layer, and

wherein said antiferromagnetic layer is

positioned between said fixed ferromagnetic layer
15 and said first diffusion barrier layer.

19. The magnetoresistance device according to
claim 18, wherein said fixed ferromagnetic layer
comprises:

a ferromagnetic layer directly contacted
5 with said tunnel dielectric layer, and

a composite magnetic layer disposed between
said ferromagnetic layer and said
antiferromagnetic layer, and

wherein said composite magnet layer is made
10 of mixture including non-oxidized metal
ferromagnetic material as main material, and
oxide material as sub material, said oxide
material being oxide of non-magnetic element more
reactive to oxygen than said metal ferromagnetic
15 material.

20. The magnetoresistance device according to
claim 19, wherein said ferromagnetic layer and
said metal ferromagnetic material included in
said composite magnetic layer is made of a metal
5 ferromagnetic alloy including cobalt as main
material.

21. The magnetoresistance device according to

claim 1, wherein said free ferromagnetic layer comprises:

a ferromagnetic layer directly contacted
5 with said tunnel dielectric layer, and

a composite magnetic layer made of mixture including non-oxidized metal ferromagnetic material as main material, and oxide material as sub material, said oxide material being oxide of
10 non-magnetic element more reactive to oxygen than said metal ferromagnetic material.

22. The magnetoresistance device according to claim 21, wherein said ferromagnetic layer and said metal ferromagnetic material included in said composite magnetic layer is made of a metal
5 ferromagnetic alloy including cobalt as main material.

23. The magnetoresistance device according to claim 1, wherein said conductor includes a second conductor electrically connected to said free ferromagnetic layer without involving said tunnel
5 dielectric layer, and

wherein said diffusion barrier structure includes a second barrier layer disposed between said free ferromagnetic layer and said second conductor.

24. The magnetoresistance device according to claim 23, wherein said second diffusion barrier layer is directly contacted with said free ferromagnetic layer, and said free ferromagnetic layer has a thickness less than 3 nm.

25. The magnetoresistance device according to claim 24, wherein a product of a saturation magnetization and a thickness of said free ferromagnetic layer is less than 3 (T·nm).

26. The magnetoresistance device according to claim 23, wherein said free ferromagnetic layer comprises a nickel-containing ferromagnetic layer including nickel, and said second diffusion barrier layer is directly contacted with said nickel-containing ferromagnetic layer.

27. The magnetoresistance device according to claim 23, wherein said free ferromagnetic layer comprises:

a ferromagnetic layer directly contacted with said tunnel dielectric layer, and

a magnetization control structure connected to said ferromagnetic layer, said magnetization control structure including non-magnetic material

and ferromagnetic material included in said
10 ferromagnetic layer.

28. The magnetoresistance device according to claim 27, wherein said magnetization control structure is non-magnetic.

29. The magnetoresistance device according to claim 27, wherein said magnetization control structure is made of oxide or nitride of ferromagnetic material included in said
5 ferromagnetic layer.

30. The magnetoresistance device according to claim 27, wherein said non-magnetic material is formed of at least one element selected from the group consisting of Ru, Pt, Hf, Pd, Al, W, Ti, Cr,
5 Si, Zr, Cu, Zn, Nb, V, Cr, Mg, Ta, and Mo.

31. The magnetoresistance device according to claim 27, wherein said non-magnetic material is segregated on grain boundary of crystals of said ferromagnetic material.

32. The magnetoresistance device according to claim 23, wherein said free ferromagnetic layer is formed so that axes of easy magnetization of

stress-induced and shape-induced magnetic
5 anisotropies are directed in a same direction.

33. The magnetoresistance device according to
claim 32, wherein a contact interface between
said free ferroelectric layer and said tunnel
dielectric layer is shaped to extend in a first
5 direction,

wherein a magnetostriction constant of said
free ferromagnetic layer is positive, and

wherein a compressive stress is exerted on
said free ferromagnetic layer in a second
10 direction orthogonal to said first direction.

34. The magnetoresistance device according to
claim 32, wherein a contact interface between
said free ferroelectric layer and said tunnel
dielectric layer is shaped to extend in a first
5 direction,

wherein a magnetostriction constant of said
free ferromagnetic layer is positive, and

wherein a tensile stress is exerted on said
free ferromagnetic layer in said first direction.

35. The magnetoresistance device according to
claim 32, wherein a contact interface between
said free ferroelectric layer and said tunnel

dielectric layer is shaped to extend in a first
5 direction,

wherein a magnetostriction constant of said
free ferromagnetic layer is negative, and

wherein a compressive stress is exerted on
said free ferromagnetic layer in said first
10 direction.

36. The magnetoresistance device according to
claim 32, wherein a contact interface between
said free ferroelectric layer and said tunnel
dielectric layer is shaped to extend in a first
5 direction,

wherein a magnetostriction constant of said
free ferromagnetic layer is negative, and

wherein a tensile stress is exerted on said
free ferromagnetic layer in a second direction
10 orthogonal to said first direction.

37. The magnetoresistance device according to
claim 32, further comprising:

a substrate; and

a lower interconnection disposed to extend
5 in a first direction between said substrate and
said free ferromagnetic layer,

wherein a magnetostriction constant of said
free ferromagnetic layer is positive, and

wherein a contact interface between said
10 free ferroelectric layer and said tunnel
dielectric layer is shaped to extend in said
first direction.

38. The magnetoresistance device according to
claim 32, wherein said further comprising:

a substrate; and

a lower interconnection disposed to extend
5 in a second direction between said substrate and
said free ferromagnetic layer,

wherein a magnetostriction constant of said
free ferromagnetic layer is negative, and

wherein a contact interface between said
10 free ferroelectric layer and said tunnel
dielectric layer is shaped to extend in a first
direction orthogonal to said second direction.

39. The magnetoresistance device according to
claim 22, wherein stress-induced magnetic
anisotropy of said free ferromagnetic layer is
stronger than shape-induced magnetic anisotropy
5 of said free ferromagnetic layer.

40. The magnetoresistance device according to
claim 39, wherein said free ferromagnetic layer
has a major axis and a minor axis perpendicular

to said major axis, and

5 an aspect ratio, defined as being a ratio
of said major axis to said minor axis, is equal
to or more than 1.0, and is equal to or less than
2.0.

41. The magnetoresistance device according to
claim 23, wherein said free ferromagnetic layer
comprises:

 a first ferromagnetic layer directly
5 contacted with said tunnel dielectric layer,

 a composite magnetic layer connected to
said first ferromagnetic layer, and made of
mixture including non-oxidized metal
ferromagnetic material as main material, and
10 oxide material as sub material, said oxide
material being oxide of non-magnetic element more
reactive to oxygen than said metal ferromagnetic
material,

 a second ferromagnetic layer including
15 nickel, and connected to said composite magnetic
layer, said second ferromagnetic layer being
magnetically softer than said composite magnetic
layer and said first ferromagnetic layer.

42. The magnetoresistance device according to
claim 40, wherein said first ferromagnetic layer

and metal ferromagnetic material included in said
composite magnetic layer are made of metal
5 ferromagnetic alloy mainly containing cobalt.

43. The magnetoresistance device according to
claim 1, wherein said free ferromagnetic layer
comprises:

a first ferromagnetic layer directly
5 contacted with said tunnel dielectric layer,

a first composite magnetic layer made of
mixture including non-oxidized metal
ferromagnetic material as main material and oxide
material as sub material, said oxide material
10 being oxide of non-magnetic element more reactive
to oxygen than said metal ferromagnetic material,

a second composite magnetic layer made of
mixture including non-oxidized metal
ferromagnetic material as main material and oxide
15 material as sub material, said oxide material
being oxide of non-magnetic element more reactive
to oxygen than said metal ferromagnetic material,

a non-magnetic layer disposed between said
first and second composite magnetic layers to
20 achieve antiferromagnetic coupling between said
first and second composite magnetic layers.

44. The magnetoresistance device according to

claim 43, wherein said first ferromagnetic layer,
said metal ferromagnetic material included in
said first composite magnetic layer and metal
5 ferromagnetic material included in said second
composite magnetic layer are made of metal
ferromagnetic alloy mainly containing cobalt.

45. The magnetoresistance device according to
claim 1, wherein said conductor includes a second
conductor electrically connected to said free
ferromagnetic layer without involving said tunnel
5 dielectric,

wherein said magnetoresistance element
further includes a magnetic biasing element
providing a bias magnetic field for said free
ferromagnetic layer,

10 wherein said magnetic bias element includes
comprises:

a magnetic bias ferromagnetic layer, and
a magnetic bias antiferromagnetic layer
including manganese and connected to said
15 magnetic biasing ferromagnetic layer, and

wherein said oxide layer includes:

a first oxide layer disposed between
said magnetic biasing element and said free
ferromagnetic layer, and
20 a second oxide layer disposed between

said magnetic biasing element and said second conductor.

46. A magnetoresistance device fabrication method comprising:

a step of forming a fixed ferromagnetic layer,

5 a step of forming a tunnel dielectric layer connected to said fixed ferromagnetic layer

a step of forming a first ferromagnetic layer on a contact surface on an opposite side of said fixed ferromagnetic layer,

10 a step of modifying an opposite portion of said first ferromagnetic layer, said portion being positioned on an opposite side of said contact surface.

47. The magnetoresistance device fabrication method according to claim 46, wherein said opposite portion is modified to be non-magnetic.

48. The magnetoresistance device fabrication method according to claim 46, wherein said step of modifying includes:

a step of nitrizing or oxidizing said
5 opposite portion.

49. The magnetoresistance device fabrication method according to claim 46, wherein said step of modifying includes:

- 5 a step of forming a non-magnetic metal layer made of non-magnetic metal on an opposite surface out of surfaces of said first ferromagnetic layer, said opposite surface is positioned on an opposite side of said contact surface, and
- 10 a step of achieving inter-diffusion between said first ferroelectric layer and said non-magnetic metal layer.

50. The magnetoresistance device fabrication method according to claim 49, wherein said material includes nickel.